EFFECTS OF RECREATIONAL DISTURBANCE ON BREEDING

BLACK OYSTERCATCHERS:

SPECIES RESILIENCE AND CONSERVATION IMPLICATIONS

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EFFECTS OF RECREATIONAL DISTURBANCE ON BREEDING BLACK OYSTERCATCHERS: SPECIES RESILIENCE AND CONSERVATION IMPLICATIONS

A

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ABSTRACT

The potential conflict between increasing recreational activities and nesting birds in coastal habitats has raised concerns about the conservation of the black oystercatcher (*Haematopus bachmani*). To address these concerns, I studied the breeding ecology of black oystercatchers in Kenai Fjords National Park and examined the impact of recreational disturbance on breeding parameters. Most recreational disturbance of breeding territories was from kayak campers and occurred after June 13, the peak hatch of first clutches. Mean annual fledging success (24%) was low, but the results suggest that daily survival rates of nests and broods did not differ between territories with and without recreational disturbance. Nest survival varied annually and seasonally, and declined during periods of extreme high tides. Daily survival rate of broods was higher on island territories than mainland territories, presumably due to differences in predator communities. Most (95%) color-banded oystercatchers returned to their breeding territories in the subsequent year regardless of level of disturbance. On average, black oystercatchers decreased incubation constancy by 39% in response to experimental disturbance. However, I found no evidence that time off the nest was associated with probability of nest survival. Further, I found no evidence that oystercatchers habituated to recreational activity. The data suggest that black oystercatchers in Kenai Fjords National Park are resilient to the current low levels of recreational disturbance.

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The US Geological Survey Natural Resources Preservation Program generously provided funding for this project. This project would not have been possible without the additional logistical and technical support of Kenai Fjords National Park. I collected data for this project during 2003-2005, and supplemented my analysis of nest and chick survival with data collected by Mike Tetreau at Kenai Fjords National Park during 2001-2002. The early work Mike did on this project greatly facilitated my efforts and enhanced the overall success of the project.

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INTRODUCTION

The black oystercatcher (*Haematopus bachmani*) is a Species of High Conservation Concern due to its small population size, low reproductive success, and dependence on habitats highly vulnerable to human disturbance (Donaldson et al. 2000, Brown et al. 2001). As ground-nesting birds in coastal habitats, oystercatchers are particularly susceptible to disturbance from recreational activities. Disturbance may be especially detrimental during the breeding season when movements are restricted and oystercatchers are highly dependent on a small breeding territory. More than half the world's population of black oystercatchers breeds in Alaska, where recreational activities in coastal habitats are rapidly increasing (Bowker 2001, Colt et al. 2002). This potential conflict has raised concerns about its conservation and management, and provided the impetus for this research. The central question of this thesis is: are breeding black oystercatchers negatively impacted by recreational activity in Kenai Fjords National Park, and if so, to what extent?

Black oystercatchers have been impacted by human disturbance throughout their range along the Pacific Coast of North America. Local extirpations of breeding populations have occurred on islands off the coast of Baja California, Mexico (Kenyon 1949, Jehl 1985) and Alaska (Andres and Falxa 1995). Additionally its congener, the European oystercatcher (*Haematopus ostralegus*) is arguably the most intensely studied shorebird in the world, and has also been impacted by human perturbations of shoreline habitats (Goss-Custard 1996). Level of impact, however, was highly dependent on the nature of the disturbance; in some areas only short-term disturbance has occurred, while elsewhere, permanent developments have destroyed critical breeding habitats.

In the United States, national parks are generally assumed to be undisturbed and protected wildlife habitats. The national parks founding legislation directed that the ecological integrity of parklands would be preserved; while at the same time parks were to be visited and enjoyed by large numbers of people (Sellars 1997). However, in many cases human recreation has proven incompatible with the conservation of species. Millions of visitors are attracted to public lands annually to engage in recreational activities; the result being that outdoor recreation has become the second leading cause for endangered species on public lands (Losos et al. 1995).

Nonetheless, effects of recreational activities on wildlife remain largely unknown. Numerous studies have been conducted, but results are often highly context- or species-specific, and rarely definitive. Most studies have focused on the immediate impacts of disturbance on individuals, as sustained long-term responses of populations or communities are harder to document. Short-term behavioral or physiological responses to recreational activity have been observed in many studies, and a few studies have documented long-term effects on reproduction and survival (reviewed in Boyle and Sampson 1985, Knight and Cole 1995, Carney and Sydeman 1999). In general, most human disturbance studies have attempted to measure disturbance effects on an absolute scale; either animals are impacted or there is no effect.

Resilience theory provides a more complex framework for qualitatively evaluating the degree of disturbance from human activity. Resilience has been defined as "the ability of systems to absorb disturbance and still maintain the same relationships between population or state variables" (Holling 1973). Applying the theory to animal populations requires the investigation of behaviors and life history traits that enable populations withstand disturbance and still persist. Thus, the natural history of a species provides clues about the relative efficacy of mechanisms that promote resilience to human disturbance (Weaver et al. 1996). Understanding these mechanisms is fundamental to developing sound management plans that promote the coexistence of recreational activity and wildlife.

The long-term resilience of a species to disturbance is partly a function of its ability to reproduce. For the first chapter of this thesis I examined productivity of black oystercatchers at Kenai Fjords National Park and the relative effects of recreational activity on nest and chick survival. Productivity is a highly variable component of avian life history and a significant proximal factor influencing population dynamics. Therefore, an understanding of oystercatcher productivity and its variability through time is critical for evaluating long-term persistence of the population. I had three objectives in this chapter: (1) determine reproductive parameters, (2) examine variation in daily survival rates of nests and broods, and (3) determine nest site fidelity. Because disturbance effects rarely happen in isolation, I examined recreational disturbance effects in the context of other ecological variables.

I also sought to identify specific mechanisms of disturbance impacts by establishing a true causal effect of recreational activity. To do this I conducted field experiments and measured incubation behavior before and during periods of experimental disturbance. Behavioral response is generally considered the most sensitive measure of disturbance effects, and is often used as an index of an animal's susceptibility to disturbance. However, level of behavior response can also be positively correlated with individual fitness, and thus may be a poor measure of susceptibility to disturbance (Beale and Monaghan 2004). Therefore, I also examined the association between level of behavioral response and the probability of nest success. I present results of these field experiments in the second chapter, and specifically (1) examine individual variation in incubation behavior in response to human disturbance, (2) examine habituation effects at two temporal scales, and (3) evaluate whether intensity of behavioral response was associated with the daily survival rate of nests.

The ultimate goal of this research was to provide management recommendations for development of a backcountry management plan in Kenai Fjords National Park. To do this I examined how productivity and incubation behavior may constrain or promote the resilience of black oystercatchers to recreational disturbance. I did not, however, examine foraging behavior, habitat selection, and predator communities, which are other parameters that could also limit resiliency or serve as thresholds to the adaptability of oystercatchers. My results provide an initial analysis of site-specific impacts from recreational activities, which is a valuable tool to managers in coastal environments to address increasing levels of recreational activity. Additionally I provided a foundation for developing a conservation strategy for the black oystercatcher throughout its range.

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CHAPTER 1. PRODUCTIVITY OF BLACK OYSTERCATCHERS: EFFECTS OF RECREATIONAL DISTURBANCE IN A NATIONAL PARK[1]

Abstract: National parks in Alaska are generally assumed to be high-quality undisturbed wildlife habitats. However, these parks also attract recreational users, whose presence may in turn reduce the suitability of key habitats for nesting shorebirds. In Kenai Fjords National Park, Black Oystercatchers (*Haematopus bachmani*) often breed on gravel beaches that are also popular campsites. In this study we examined effects of recreational activities in coastal Alaska on reproductive performance of Black Oystercatchers. We monitored survival of nests and chicks on 35 to 39 breeding territories annually from 2001-2004. Most recreational disturbance on breeding territories was from kayak campers and occurred after the peak hatch of first clutches. Annual productivity was low (0.35 chicks/pair) but was not adversely affected by recreational disturbance. Daily survival of nests varied annually and declined over the season. Our results suggest that nest survival was lower during periods of extreme high tides. Daily survival rate of broods increased over the season and was higher on island than mainland territories, likely due to differences in predator communities. Occupancy rate of territories and site fidelity was high; 95% of color-banded oystercatchers returned to the same breeding territories in the subsequent year. We conclude that Black Oystercatchers are resilient to low levels of recreational disturbance. However, in light of projected increases in

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recreation we suggest managers move campsites away from the traditional nest sites identified in this study.

Key words: Black Oystercatcher, national park, nest survival, productivity, recreational disturbance.

INTRODUCTION

Recreational activities are the fourth leading cause of population declines of species listed as federally threatened or endangered, behind only exotic species, urbanization, and agriculture (Czech et al. 2000). Recreational activities are a growing conservation concern because they are rapidly increasing in the U.S. (Boyle and Sampson 1985, Flather and Cordell 1995), and likely worldwide. In some cases disturbance from recreationists has been shown to have short-term effects on wildlife behavior and physiology, and long-term effects on reproduction and survival (see reviews Boyle and Sampson 1985, Knight and Cole 1995, Carney and Sydeman 1999). However, there remains considerable debate about the effect of human disturbance on avian populations (Hill et al. 1997, Nisbet 2000).

The long-term resilience of a species to disturbance is a function in part of its ability to reproduce. Understanding the processes that affect reproductive success is crucial for developing effective management or conservation plans. Ground-nesting birds, including shorebirds, generally have low rates of reproductive success, with predation being the predominant cause of nest failures (Evans and Pienkowski 1984). Ground-nesting birds in coastal habitats are also particularly vulnerable to human disturbance, given the propensity for humans to live and recreate in these regions (Burke et al. 2001). These combined threats have resulted in population declines and the listing of several beach-nesting shorebirds as endangered species (e.g., Western Snowy Plover (*Charadrius alexandrinus nivosus*), Page et al. 1995; Piping Plover (*C. melodus*), Dyer et al. 1988; New Zealand dotterels (*C. obscurus)*, Dowding 1993).

Black Oystercatchers (*Haematopus bachmani*) have also been affected by human disturbance throughout their range along the Pacific Coast of North America. Local extirpations of breeding populations have occurred on islands off the coast of Baja California, Mexico (Kenyon 1949, Jehl 1985) and Alaska (Andres and Falxa 1995). Further, human disturbance has caused changes in abundance and distribution of breeding oystercatchers from California to Alaska (Andres and Falxa 1995). More than half the world's Black Oystercatcher population breeds in Alaska, where recreational activities are increasing (Bowker 2001, Colt et al. 2002). Consequently, the Black Oystercatcher has been designated as a Species of High Conservation Concern (Alaska Shorebird Working Group 2000, Brown et al. 2001).

From a management perspective, human impacts are generally regarded as those that can be measured in terms of effects on population size. Productivity is a highly variable component of avian life history, which significantly influences population dynamics. Black Oystercatchers are ground-nesters with semi-precocial young, thus their reproductive success may be lower in areas with human disturbance. Additionally, long-lived iteroparous species such as the Black Oystercatcher (average lifespan is greater than 10 years; Andres and Falxa 1995) have many opportunities to breed in a lifetime;

therefore, individuals may reduce reproductive effort when breeding conditions are unfavorable (Stearns 1992). Black Oystercatchers may lower reproductive effort in areas with human disturbance by foregoing nesting or re-nesting. Finally, productivity could also be impacted by human disturbance as breeding pairs may be displaced from, or have lower site fidelity to, areas with recreational disturbance.

Over the past decade, recreational use of backcountry coastal habitats in Kenai Fjords National Park has increased (Tetreau 2004), causing concern by park managers and providing impetus for this study. Our primary goal was to acquire baseline data on the breeding ecology of Black Oystercatchers, while levels of recreational use in the park were still relatively low compared to national parks elsewhere in the United States. The objective of this research was to determine if daily survival rates and site fidelity differed at sites with recreational disturbance. The park included areas impacted differentially by recreational disturbance, allowing comparisons between areas with different levels of human use. Specifically, we examined sources of variation in daily survival rates of nests and broods. In our analyses, we simultaneously considered both ecological and recreational disturbance effects on survival rates. From our research, we suggest management recommendations in light of projected increases in recreational activities in the park.

METHODS

STUDY AREA

This study was conducted in Aialik Bay (59°52`N, 149°39`W) and Northwestern Fjord (59°45'N, 149°53'W), the two most popular coastal destinations of tourists in Kenai Fjords National Park (Figure 1). Mountains, tidewater glaciers, deep bays, and steep, rocky and convoluted shorelines characterize the study area. The study area is remote, accessible only by boat, and approximately 60 km across the Gulf of Alaska from the nearest town of Seward, Alaska. Most tourists visit the coastal areas of Kenai Fjords National Park on tour boats and never set foot on the shoreline; only 1% of park visitors stay overnight in the backcountry (Colt et al. 2002).

Recreational activities on the shoreline were primarily limited to kayak camping, and isolated to low-sloped gravel beaches because much of the shoreline was too steep for landing a small boat. With over 150 km of shoreline in the study area, there were only 25 camping beaches, 12 of which were established campsites (with permanent bear lockers for food storage) and used regularly. It was difficult to quantify the amount of human use over such a large area; the best data available came from Park Ranger's patrols and were limited to Aialik Bay (Tetreau 2004). These data show the number of kayak campers in the study area in general was low and varied annually and seasonally, with peak use on weekends in July (Figure 2).

FIELD METHODS

Crews of two to four people conducted fieldwork from mid-May to mid-August, 2001 – 2004. We systematically surveyed 150 km of shoreline each year by boat; when a territorial pair of oystercatchers was observed, the area was searched on foot for a nest. Once a nest was found, it was checked on average every six days (2001-2002), or every four days (2003-2004), until chicks fledged or the nest/brood failed. Similar research on European Oystercatchers (*H. ostralegus*) showed frequent nest visits did not affect breeding success (Verboven et al. 2001). Regardless, on subsequent visits we often could observe a bird incubating from the boat without flushing it off the nest, thus we minimized researcher disturbance. We considered a nest successful if we observed at least one chick; and a brood was successful if at least one chick was observed flying. When a nest failed the immediate area was searched for shell fragments, predator tracks, or evidence of recent flooding (Mabee 1997). In 2003 and 2004, we floated two eggs in each clutch to estimate hatch date (Dinsmore et al. 2002).

We began capturing and banding birds with unique color bands for individual identification in 2003. Adults were captured during early incubation at the nest site with either a dipnet or noose mats. Most oystercatchers returned to incubating eggs before we departed the territory, therefore we do not suspect our research activities impacted nesting success. All chicks were banded between 10 and 20 days post hatch. Capture and banding activities were conducted under appropriate permits from University of Alaska, Fairbanks Institutional Animal Care and Use, and USGS Bird Banding Laboratory.

STATISTICAL ANALYSES

We calculated the following components of reproductive success: mean clutch size, percent of females renesting, nesting success (nests hatching at least one chick / total nests), fledging success (nests fledging young / nests hatched), and productivity (chicks fledged / pair). Mean pair productivity (chicks fledged / years territory occupied) was also calculated for territories occupied in multiple years of the study. Return rate (individuals resighted / individuals marked) was calculated based on resightings of color-banded oystercatchers throughout the 2004 breeding season. These descriptive statistics are presented for comparison with other studies.

We used program MARK to model the daily survival of Black Oystercatcher nests and broods, with respect to recreational disturbance and other ecological variables (Dinsmore et al. 2002, Cooch and White 2005). We examined year- and time- specific variation in survival rates, and simultaneously evaluated the importance of individual covariates on daily survival rates. We used an information-theoretic approach for model selection and evaluated models using AIC corrected for small sample size (Burnham and Anderson 2002). We used model-averaged parameter estimates to indicate effect size of individual covariates. Currently, there is no goodness-of-fit test for nest survival data in program MARK (Dinsmore et al. 2002); therefore, we estimated variance inflation factor values ($\hat{c}$ = deviance of the global model/ df). This estimate of overdispersion is known to be positively biased (Dinsmore et al. 2002), therefore we report this value but did not adjust model selection statistics. Hatching and fledging survival probabilities were calculated as the product of daily survival rates, and variances for those estimates were calculated with the delta method (Seber 1982).

We limited our analyses to a small set of *a priori* models to address our questions of interest without over-fitting the data. First we considered a model in which survival was constant, comparable to traditional Mayfield (1975) techniques of estimating survival. We then modeled daily survival rates of nests and broods relative to year and temporal trends within year; we examined models with a linear and quadratic trend in survival over the nesting season. Temporal trends within season may be confounded with nest age (Klett and Johnson 1982, Dinsmore et al. 2002); however, nests were initiated throughout the season due to renesting. We did not treat nest age as a separate covariate because we lacked accurate estimates of nest age in all years.

We examined variation in nest and brood survival rates relative to three categorical covariates: we hypothesized that (1) survival rates on territories within 200 meters of an established campsite would be lower than territories with no camping disturbance, (2) predation rates, and therefore survival, would vary between territories on the mainland and island territories, and (3) survival rates would be lower during periods of extreme high tides due to a higher potential for nests to be flooded. We treated tide height as a categorical covariate because we expected a threshold effect; extreme tide periods were defined as days when the maximum observed tide height (data obtained from NOAA station in Seward, AK) was greater than monthly mean high high water. We added structure to the best temporal model (year and date effects) by modeling additive effects of landform and tide covariates, and their interaction. Once we had determined the most parsimonious model from this set we compared this model to a model with the same structure and the campsite covariate added. This model building strategy provided the best means to evaluate a campsite effect, our primary objective (Leberton et al. 1992)

Nest and brood survival were likely independent with respect to temporal variation and covariate effects; therefore these were treated as separate analyses. Survival rates derived from these analyses, however, are not independent as the same pairs and locations were used in both analyses. Estimated hatch dates (derived either from direct observation or egg flotation data) were used to split exposure days between the nest and brood analyses. In cases (n = 14) where hatch date was unknown, we used the midpoint between the last nest visit and the first chick visit as the estimated hatch date. Lack of precise estimates of hatch dates for all nests may bias our estimates of daily survival probability (Stanley 2000); however, we visited nests frequently and therefore expected this bias to be small.

RESULTS

BREEDING ECOLOGY

We monitored the reproductive success of 35 to 39 breeding pairs annually (Table 1). Eight to twelve pairs nested each year on steep rocky islands; the remaining pairs nested on mainland gravel beaches. Eight of these beaches were also established campsites regularly used by kayak campers. Recreational disturbance at these campsites was more frequent starting in mid-June, after peak hatch of oystercatcher nests (Figure 2). Most breeding territories were occupied in multiple years, and 21 territories were occupied in all four years of the study (Figure 1). We banded 45 breeding adults in 2003, and with the exception of two pairs, at least one individual from every known breeding pair in the study area was banded. Almost all (n = 43) birds banded in 2003 returned and bred again in 2004; except for two individuals, all returned to the same breeding territory.

For 2003 and 2004 we estimated that at least 65% of our nest failures were likely due to predation. Evidence of specific predators was rarely apparent; however, we were able to attribute 8% of these depredated nests to black bears (*Ursus americanus*), and 6% to avian predators. Over the four years of this study we observed various predators taking oystercatcher eggs and chicks, including black bears, wolverines (*Gulo gulo)*, river otters (*Lutra canadensis*), Bald Eagles (*Haliaeetus leucocephalus)*, and Common Ravens *(Corvus corax)*. Flooding or other natural causes accounted for roughly 6% of nest failures, and approximately 6% of nests were abandoned; cause of failure for the remaining 23% was unknown.

NEST SURVIVAL

Daily survival rates of nests varied annually and declined as a quadratic function of date (Table 2, Figure 3). The campsite covariate explained very little variation in survival rates, adding this covariate to the most parsimonious model did not improve model fit and only slightly decreased the model deviance (Table 2). Evidence was strong that tide influenced nest survival; there was a trend towards lower survival during periods of extreme high tides (β_{tide} = -0.37, 95% CI: -0.86 — 0.13). There was also some support for an effect of landform on nest survival, but this parameter was not precisely estimated ($\beta_{landform}$ = -0.13, 95% CI: -0.53 — 0.27). There was no support for the null model in which daily survival was constant, comparable to simple Mayfield estimates. Model-averaged estimates of annual nest survival for a nest hatching on 13 June (mean hatch date) were 0.32 (95% CI: 0.17 – 0.46), 0.25 (95% CI: 0.12 – 0.38), 0.48 (95% CI: 0.32 – 0.64), and 0.22 (95% CI: 0.10 – 0.33), 2001 – 2004 respectively (Figure 4). Estimated variance inflation factor ($\hat{c}$) for this analysis was 3.1.

BROOD SURVIVAL

Daily survival rates of broods increased as a linear function of season date and did not vary annually (Table 3). There was little support for a campsite effect on brood survival, adding the campsite covariate to the most parsimonious model did not improve model fit and only slightly decreased model deviance. Survival of chicks was higher on island territories than mainland territories ($\beta_{landform}$ = -0.98, 95% CI: -1.87 — -0.09). There was some support for an effect of tide on brood survival, and an interaction between tide and landform, but these parameters were not precisely estimated (β_{tide} = -1.57, 95% CI: -3.73 — 0.59, $\beta_{tide*landform}$ = 1.51, 95% CI: -0.93 — 3.95). Model-averaged estimate of brood survival to 40 days for a nest hatched on 13 June, was 0.46 (95% CI: 0.30 – 0.63; Figure 4). Estimated variance inflation factor ($\hat{c}$) for this analysis was 3.2.

DISCUSSION

During the four years of this study, we monitored the survival of 500 eggs, from which only 51 chicks fledged. Low estimates of reproductive success were similar to those reported for Black Oystercatchers in other areas (Andres and Falxa 1995, Murphy and Mabee 2000, Hazlitt 2001); the exception being Middleton Island, a relatively predator-free island in the Gulf of Alaska, where estimates of nest success were considerably higher (Gill et al. 2004). Similar to these studies, we found substantial annual variation in survival rates of nests, and most nest failures were due to predation. Evidence of specific predators was rarely apparent in Kenai Fjords, but the suite of potential predators was extensive. Due to the low density of breeding oystercatchers, we considered all to be opportunistic predators. We suggest the high temporal and spatial variability in breeding success of Black Oystercatchers was primarily due to local variation in predator abundance.

Despite low estimates of productivity, we found no evidence that survival rates of nests or broods were adversely affected by recreational disturbance in Kenai Fjords National Park. This result contrasts with other recent studies on beach-nesting shorebirds exposed to recreational disturbance (Ruhlen et al. 2002 and references therein). However, the level of recreational disturbance in our study area was considerably lower than other areas studied, was not consistent throughout the breeding season, and affected only a small number of territories. Additionally, some predators in our study area, namely black bears, may be deterred from areas with human disturbance. Levels of recreational disturbance in Kenai Fjords increased starting in mid-June, after the peak hatch of oystercatcher nests. Thus brood-rearing was potentially the most vulnerable breeding stage, yet we didn't detect any effects of recreational disturbance on brood survival. Our ability to detect differences in daily survival rates of broods reared on popular campsites may have been precluded by low hatching success and the resultant small sample size. We suggest a threshold level for recreational disturbance may exist below which productivity is not affected, or effects are not detectable.

Factors other than recreational disturbance did explain variation in daily survival rates of nests and broods. Our results provide evidence that survival rates of nests were lower during periods of extreme high tides. Black Oystercatchers typically nest close to the high tide line and are therefore highly vulnerable to flooding events (Andres and Falxa 1995). Daily survival of chicks was higher on island territories than on mainland beaches. This result contradicts other studies that demonstrated higher breeding success of Black Oystercatchers on shallow-sloped territories (Andres 1998, Hazlitt et al. 2002). Slope of the breeding territory has been used as an indicator of forage availability; presumably lower slope territories have more forage available and are more directly accessible to chicks. However, predation rates may override any advantage incurred from better forage on shallow-sloped shorelines. The suite of potential predators was certainly more limited on island territories; only avian predators were typically observed at these sites. Common Ravens are typically a primary predator at other areas (Andres 1999), but we observed few ravens in our study area. Thus higher brood survival on island territories was likely a result of lower predation rates at these sites, and may have been a very localized effect.

We also found that Black Oystercatchers exhibited strong site fidelity to their breeding territories, consistent with other studies (Hazlitt and Butler 2001 and references therein). High site fidelity in 2004 may have been correlated with the high breeding success in 2003 (Hazlitt and Butler 2001). Breeding site fidelity can provide ecological benefits through familiarity with forage and local predator communities (Oring and Lank 1984). These ecological advantages may then contribute to improved nest success, increased survival, and improved feeding efficiency. We could not directly assess the effect of disturbance on site fidelity because very little recreational disturbance occurred during the critical period in early May when pairs were establishing territories. However, we suspect that Black Oystercatchers are unlikely to be displaced from breeding territories due to recreational disturbance; ecological advantages of site fidelity, combined with the potential lack of alternative nest sites on the rocky coastline (Hockey 1996), would likely override avoidance of areas with human activity, except in cases of extreme disturbance (e.g., development).

Our study illustrates that low productivity of Black Oystercatchers in Kenai Fjords National Park was primarily due to ecological, not direct anthropogenic factors. Nevertheless, the projected increase in recreational disturbance in the park is a cause for concern, as responses of oystercatchers to higher levels of disturbance are currently unknown. Thus, we encourage resource managers to take the 'precautionary principle' approach in managing recreational disturbance. While managers can do little to control ecological variables, we suggest preventative management actions can be taken that would minimize disturbance during critical breeding stages. For example, given the strong site fidelity observed in Black Oystercatchers, established campsites could be moved away from the nest sites identified in this study. Managers of Kenai Fjords National Park have the unique opportunity to largely control where people camp because most recreationists use established campsites with food storage lockers for bear protection. Due to the high levels of predation observed, we further suggest more research is needed on the effects of recreational disturbance on predator communities.

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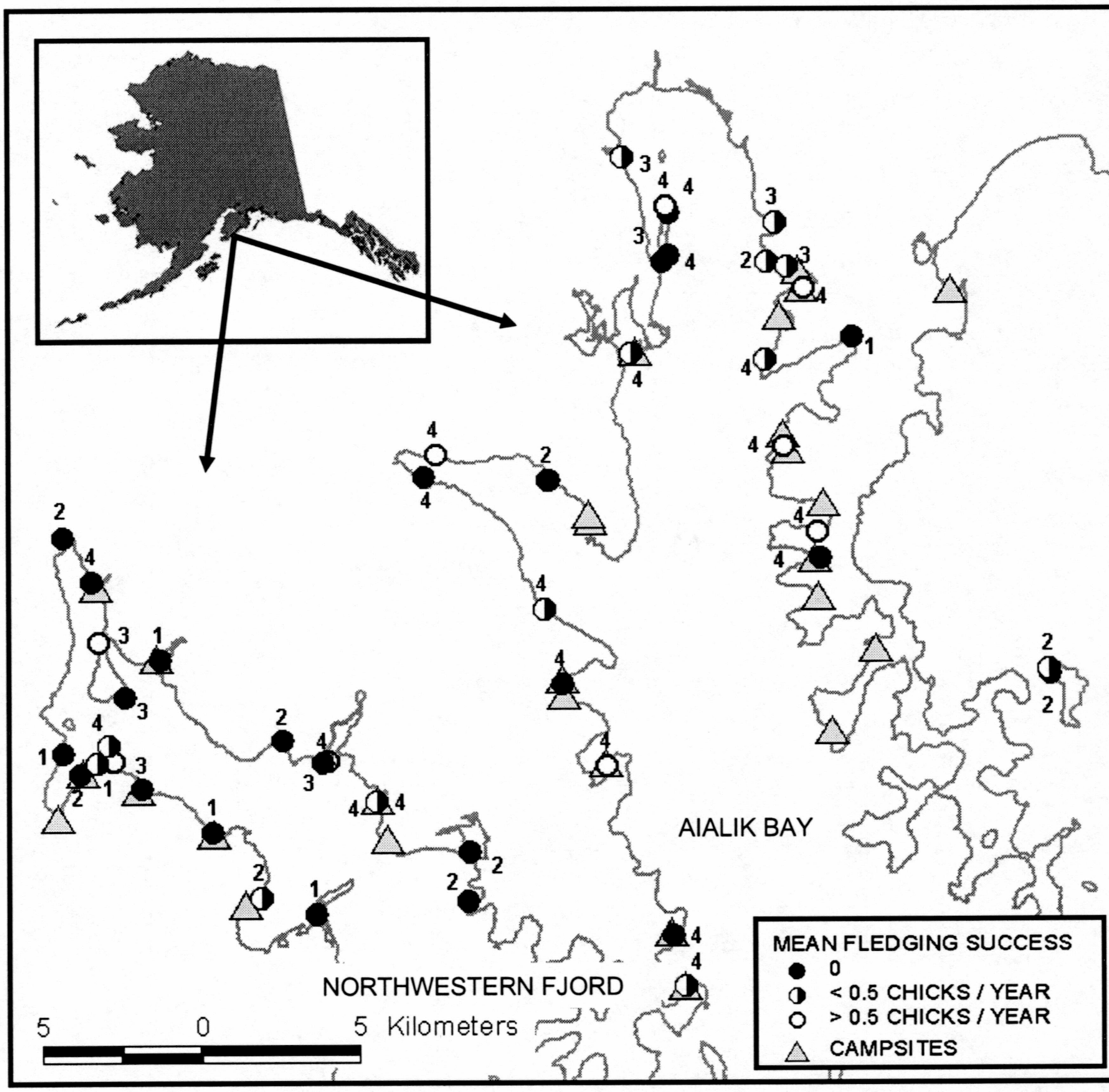

FIGURE 1-1. Location and fledging success of breeding territories in Kenai Fjords National Park monitored from 2001 – 2004. The number beside each territory indicates the number of years (max. = 4) the site was occupied.

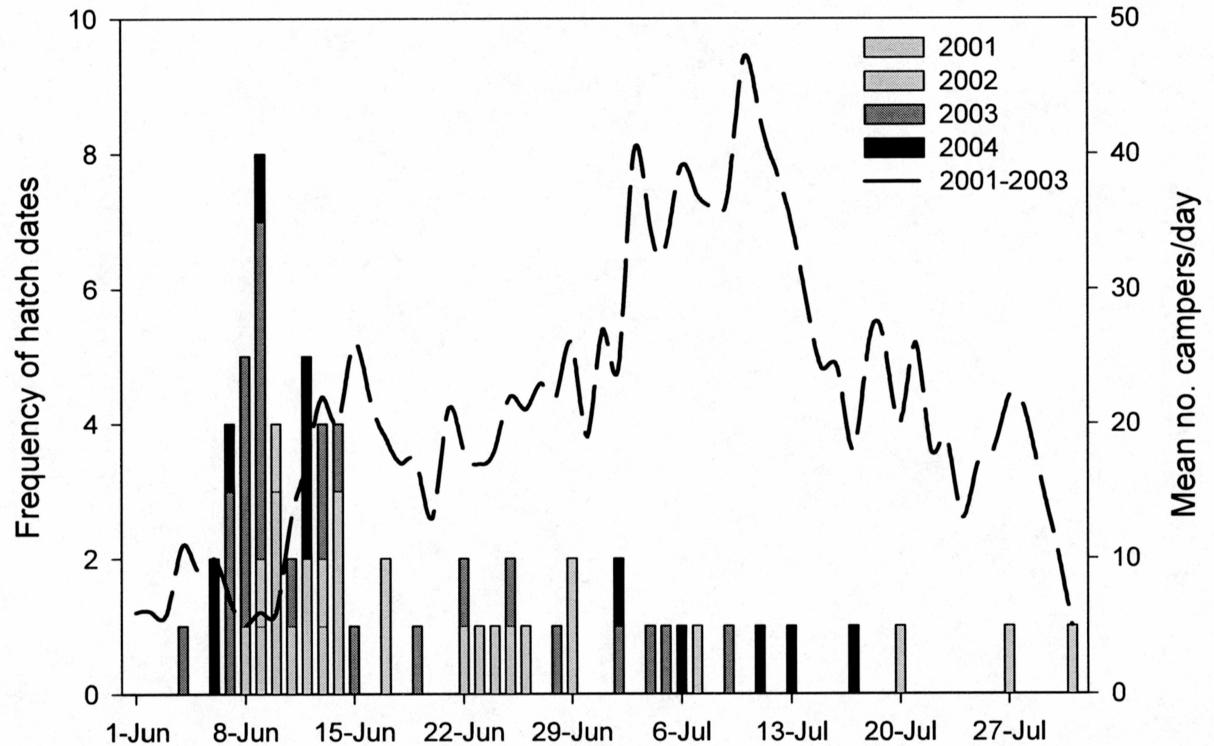

FIGURE 1-2. Comparison of breeding chronology and level of recreational disturbance in Kenai Fjords National Park. Solid bars show histogram of Black Oystercatchers hatch dates from 2001 — 2004, and dotted line shows the mean number of campers in Aialik Bay each day from 2001 — 2003.

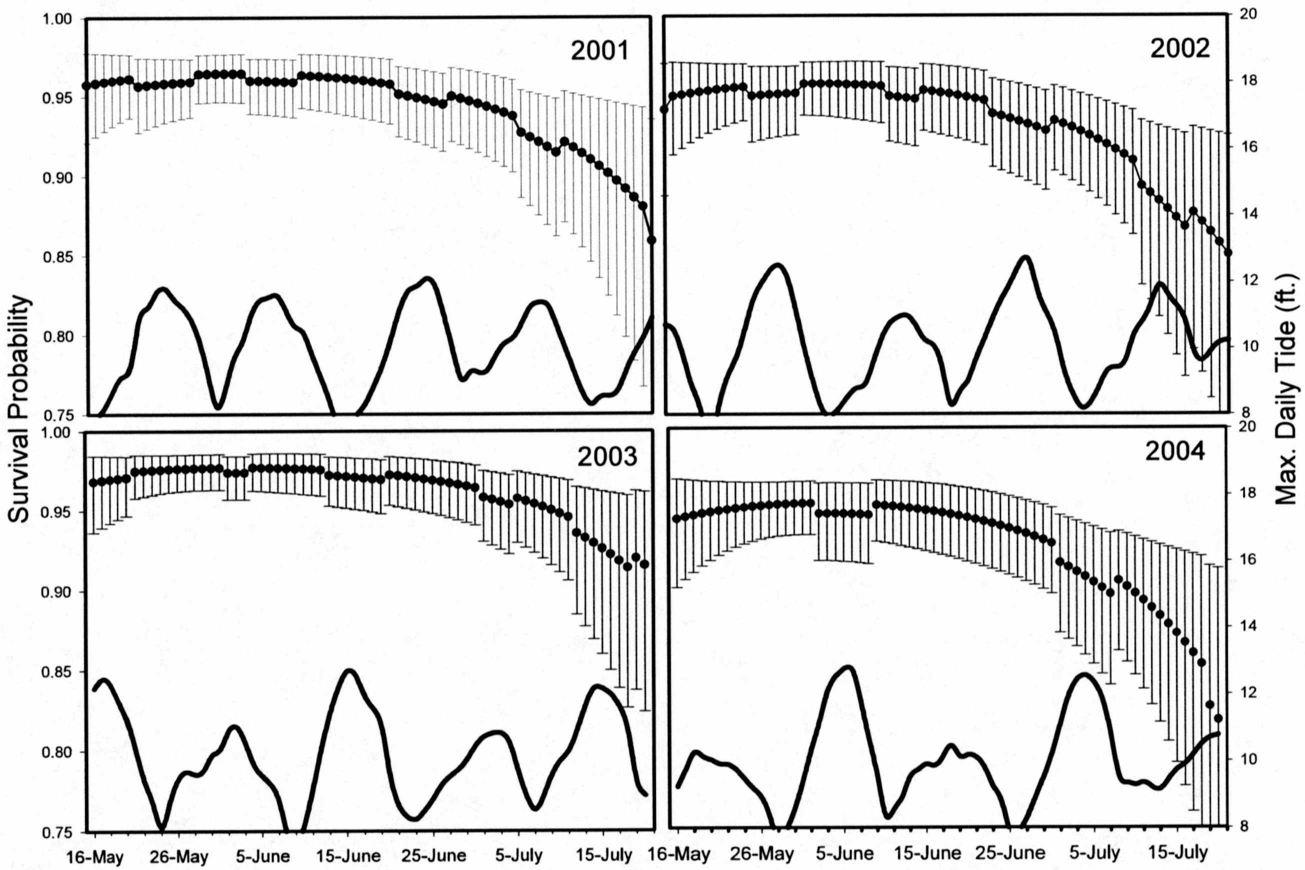

FIGURE 1-3. Comparison of daily survival rates of Black Oystercatcher nests and maximum daily tide height at Kenai Fjords National Park, 2001 — 2004. Model average estimates ± 95% CI were calculated using weighted averages based on the AICc score of each candidate model.

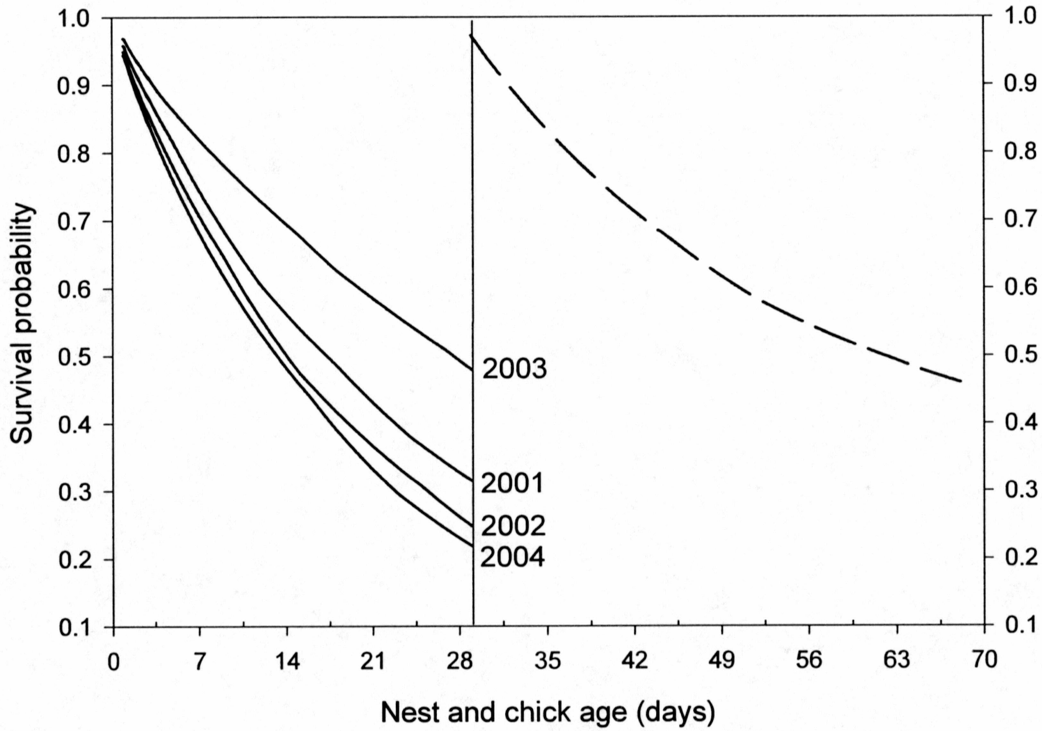

FIGURE 1-4. Cumulative survival curves for Black Oystercatcher nests (solid lines) and broods (dashed line) in Kenai Fjords National Park, 2001 — 2004. The vertical line represents hatch, estimates are based on a mean hatch date of 13 June. Values are the product of model averaged daily survival estimates for nests, and daily survival estimates derived from the best model for broods.

TABLE 1-1. Annual measures of reproductive success of Black Oystercatchers in Kenai Fjords National Park from 2001 — 2004. Values are means ± SE.

	2001	2002	2003	2004	MEAN
No. breeding pairs	35	36	37	39	36.8
Mean clutch size	2.7 ± 0.1	2.6 ± 0.1	2.6 ± 0.1	2.5 ± 0.1	2.6 ± 0.1
Females renested (%)	31 ± 8	50 ± 8	32 ± 8	44 ± 8	40 ± 3
Nesting success (%)	31 ± 7	26 ± 6	51 ± 7	20 ± 5	32 ± 3
Fledging success (%)	50 ± 12	71 ± 12	44 ± 10	46 ± 15	52 ± 6
Productivity (young/pair)	0.4 ± 0.1	0.4 ± 0.1	0.5 ± 0.1	0.2 ± 0.1	0.4 ± 0.1

TABLE 1-2. Ranking of *a priori* models estimating daily survival rates of Black Oystercatcher nests at Kenai Fjords National Park, 2001-2004. Models were ranked based on Akaike's Information Criterion adjusted for small sample size (ΔAIC*c*).

NEST SURVIVAL[1]	K[2]	AIC_c[3]	$\Delta AICc$[4]	w_i[5]	DEV[6]
Year + temporal^2 effects	6	636.45	0.00	0.30	624.41
Year + temporal^2 + tide effects	7	636.45	0.01	0.30	622.41
Year + temporal^2 + landform effects	7	638.03	1.59	0.14	623.99
Year + temporal^2 + campsite effects	7	638.41	1.96	0.11	624.37
Year + temporal effects	5	638.82	2.37	0.09	628.80
Year + temporal^2 + landform + tide + landform*tide	9	639.98	3.53	0.05	621.91
Year effects only	4	645.88	9.44	0.00	637.87
Null model: DSR is constant	1	650.71	14.26	0.00	648.71

[1] Date parameters: temporal effect is a linear trend with season date, temporal^2 is a linear plus quadratic trend with season date
[2] No. of parameters
[3] Akiake's Information Criterion corrected for small sample size
[4] Difference in AICc from the best model
[5] Model weight
[6] Model deviance

TABLE 1-3. Ranking of *a priori* models estimating daily survival rates of Black Oystercatcher broods at Kenai Fjords National Park, 2001-2004. Models were ranked based on Akaike's Information Criterion adjusted for small sample size ($\Delta AICc$).

BROOD SURVIVAL[1]	K[2]	AIC_c[3]	$\Delta AICc$[4]	w_i[5]	DEV[6]
Temporal + landform effects	3	211.91	0.00	0.44	205.89
Temporal + landform + tide + landform*tide effects	5	213.47	1.57	0.20	203.44
Temporal + landform + campsite effects	4	213.69	1.79	0.18	205.67
Temporal effects only	2	215.51	3.60	0.07	211.50
Temporal + tide effects	3	216.77	4.86	0.04	210.75
Null model: DSR is constant	1	216.84	4.93	0.04	214.84
Temporal^2 effects only	3	217.51	5.60	0.03	211.49
Year effects only	4	220.86	8.95	0.01	212.83

[1] Date parameters: temporal effect is a linear trend with season date, temporal^2 is a linear plus quadratic trend with season date
[2] No. of parameters
[3] Akiake's Information Criterion corrected for small sample size
[4] Difference in AICc from the best model
[5] Model weight
[6] Model deviance

CHAPTER 2. EXPERIMENTAL EFFECTS OF RECREATIONAL DISTURBANCE ON BREEDING BLACK OYSTERCATCHERS IN KENAI FJORDS NATIONAL PARK.[1]

Abstract. Coastal habitats worldwide receive a great deal of human disturbance, particularly from recreational activities. As outdoor recreation is becoming increasingly popular, concerns have been raised about its effects on wildlife populations. Of particular concern is the potential conflict between increasing recreational activities and ground-nesting birds in coastal habitats. To assess the impact of recreational activities on breeding black oystercatchers *Haematopus bachmani*, we conducted field experiments in 2004 and 2005 and quantified the time spent off the nest in response to a controlled amount of recreational disturbance. Oystercatchers breeding in the study area had been previously banded, thus we were able to examine individual-level responses over time and evaluate habituation effects. We also examined the impact of recreational disturbance on population dynamics by evaluating the influence of behavioral response on nest survival. Black oystercatcher pairs decreased incubation constancy by an average of 39% in response to experimental disturbance. There was no difference between males and females in response to disturbance; both decreased their time at the nest. We found no evidence that oystercatchers habituated to recreational disturbance, either within seasons or between years. After accounting for annual and seasonal variation, time spent off the nest did not explain any additional variation in the daily survival rate of nests.

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We concluded that experimental disturbance impacted individual behavior, but not population dynamics. Our data suggest intensity of behavioral response may be a poor metric of disturbance impacts, thus we recommend management plans incorporate multiple measures of disturbance impacts.

Keywords: disturbance; habituation; *Haematopus bachmani*; incubation constancy; nest attendance; nest survival

INTRODUCTION

Determining the extent to which wildlife populations are impacted by human activity is a crucial, albeit challenging, task in conservation biology. Effects of human disturbance, particularly from recreational activities, are complex and difficult to quantify, and can have both short- and long- term consequences on individuals and populations. Behavioral response is often considered the most sensitive measure of human disturbance, and is therefore the most common index used to assess human disturbance impacts on breeding birds (reviewed in Carney and Sydeman, 1999; see also Beale and Monaghan, 2004a; Gill et al., 2001). Strength of behavioral response is used as a measure of susceptibility, with the most responsive animals assumed to be the most vulnerable to human disturbance. However, individual response may be more dependent on individual fitness than strength of the disturbance event, as the more fit individuals may be able to afford the greatest behavioral response (Beale and Monaghan, 2004a).

Further, behavioral response may attenuate as an individual can become habituated to human disturbance.

To evaluate the long-term effects of human disturbance, it is critical to assess how behavioral response to disturbance affects population demographic parameters such as survival and productivity. Most recreational activities do not involve direct consequences on survival, but population dynamics can be indirectly impacted through behavioral or physiological responses. For example, it is often assumed that decreases in incubation behavior in response to human disturbance will result in lower rates of reproductive success, thereby reducing long-term population viability. Birds often perceive humans as potential predators and will generally flush off the nest when approached by humans, thereby leaving their eggs exposed to predation and inclement weather (Beale and Monaghan, 2004b; Bolduc and Guillemette, 2003). Numerous papers have demonstrated decreased incubation constancy in the presence of humans (Carney and Sydeman, 1999; Steidl and Anthony, 2000; Verhulst et al., 2001); few, however, have demonstrated a significant association between changes in incubation behavior and breeding success (Nisbet, 2000).

Black oystercatchers are a species of high conservation concern due to their small population size, low rates of reproductive success, and dependence on habitats highly vulnerable to human disturbance (Brown et al., 2001). Given the propensity of humans to live and recreate in coastal areas, the breeding territories of oystercatchers are often exposed to human activities (Burger, 1995). As levels of recreational activities are rapidly increasing (Flather and Cordell 1995), it is increasingly important to quantify the effects of this disturbance type.

We conducted manipulative experiments, using pairs as their own control, to assess the effects of recreational disturbance on incubation behavior of black oystercatchers. Specifically, we investigated whether there was a causal relationship between recreational disturbance and incubation constancy, and quantified the level of impact. We replicated the experiment on known individuals to assess whether oystercatchers habituated to human disturbance. Finally, to examine the link between incubation behavior and nest survival, we evaluated the influence of time spent off the nest on the probability of nest survival.

METHODS

STUDY AREA

Kenai Fjords National Park is a remote coastal area characterized by mountains, tidewater glaciers, and deep fjords. Our study area consisted of over 150 km of convoluted shoreline within Aialik Bay (59°52'N, 149°39'W) and Northwestern Fjord (59°45'N, 149°53'W), the two most popular coastal destinations in the park. There are no roads in the study area; it is accessible only by boat, approximately 60 km across the Gulf of Alaska from the nearest town of Seward, Alaska. While one of the most popular national parks in Alaska, 99% of tourists visit on tour boats and never set foot on the shoreline (Colt et al., 2002). Recreational activities on the shoreline were primarily limited to camping by kayakers, and were concentrated on low-sloped gravel beaches, as much of the shoreline is too steep for landing a kayak or other small boat. In general, recreational use of these beaches was low and varied annually and seasonally, with peak use on weekends in July (Tetreau, 2004).

Breeding ecology of black oystercatchers has been studied at Kenai Fjords National Park since 2001 (Morse et al., *in review*). Breeding territories were located during annual shoreline surveys, and survival of nests and chicks was monitored every four to seven days until chicks fledged or the pair abandoned the territory. We trapped and banded incubating adults in 2003; birds were marked with a unique combination of color bands and a U.S. Fish and Wildlife Service identification band. A 1-cc blood sample was collected from the wing at capture for DNA-based sex determination (Griffiths et al., 1998).

EXPERIMENTAL PROTOCOL

Short-term disturbance experiments were conducted in 2004 and 2005 to assess the response of black oystercatchers to human disturbance. Experiments were conducted on all beach nests once we found evidence that adults had begun incubation (determined through egg flotation). Our experimental design consisted of three replicate experiments conducted per pair within the 29-day incubation period of oystercatchers; however, nests often failed before we were able to complete replicate experiments. We monitored survival of nests immediately post-experiment and on the subsequent day to determine if our experiments had caused pairs to abandon the nest. A sample of banded pairs was included in both years of the study

The experimental protocol consisted of paired one-hour observation periods, a control period followed by a disturbance period. We did not vary the sequence of treatments because of the potential for a carryover effect from the disturbance treatments. In both treatments, an observer, hidden from the nest as much as possible in the surrounding vegetation or rocks, continuously recorded the time both adults spent incubating the nest. To account for any immediate disruption of the birds' behavior due to the observer's arrival, the experiment began ten minutes after the observer arrived. During the control period, the observer was the only human near the nest. In the second hour a field assistant acted like a recreationist establishing a campsite. The "camper" set up a tent 50 m from the nest and remained active within a 50 m radius of the nest for the entire observation hour. At two points during the observation hour the camper walked a transect parallel to the shoreline, 5 m from the nest. Our experiments sought to mimic the most active period of camp establishment, however, true camping disturbance is longer in duration; our results should therefore be considered a conservative estimate of how disturbance may affect oystercatchers.

STATISTICAL ANALYSES

We examined behavioral response to disturbance on both the individual and pair level. Nest attendance was calculated for each sex as the percentage of time each individual incubated the nest. We calculated incubation constancy as the percentage of time eggs were incubated (defined as either adult sitting on the eggs) during each one-hour observation period. To examine the null hypothesis that there were no differences in incubation constancy between control and disturbance treatments, we used a paired t-test. We conducted this analysis using only data from the first experiment on each nest (*n* = 37) to ensure repeated sampling of the same experimental unit (nests) did not bias our interpretations. All subsequent analyses used the measured difference in incubation constancy between control and disturbance treatments as the response variable.

We tested for evidence of habituation to experimental disturbance at two temporal scales, within seasons and between years, using repeated measures ANOVAs. We hypothesized that if oystercatchers habituated to recreational disturbance the treatment effect (difference in incubation constancy between control and disturbance treatments) would diminish over time. To test for short-term habituation we examined whether there was a temporal trend within seasons in the treatment effect, using experimental replicates as the repeated measures. For this analysis each pair was a blocking factor and year was treated as a fixed factor. To examine inter-annual trends in response to experimental disturbance, we compared responses of those pairs observed in both years of the study. In this analysis we compared the treatment effect from the first experiment in each year; pair was again the blocking factor and year was the repeated measure.

To examine the link between incubation behavior and nest survival, specifically whether less attentive pairs had lower nest survival rates, we used the nest survival module in Program MARK. In this program we treated behavioral response to disturbance as an individual covariate, and examined whether it explained any variation in daily survival rate. Our previous research (Morse et al., *in review*) had determined the best model structure and most important sources of variation in daily survival rate. Thus, we were able to use this model structure and account for additional sources of variation, while examining the influence of behavioral response on nest survival. We examined only a small set of *a priori* models to address only questions pertaining to behavioral impacts (Table 1). For each nest we used the difference in incubation constancy between control and disturbance treatments on the first experiment as the behavioral covariate. We standardized this measure in program MARK so that the covariate had a mean of zero and ranged from –3 to 3. We used an information-theoretic approach for model-selection and evaluated models using AIC corrected for small sample size (Burnham and Anderson, 2002).

We used square root transformations where necessary to meet the assumptions of parametric statistical tests; but we present means ± SE from untransformed linear data, rather than retransformed values, to facilitate interpretations. All data were analyzed either in SAS (SAS Institute, 1999) using two-tailed tests and a significant level of $P \leq 0.05$, or Program MARK (Cooch and White, 2005).

RESULTS

On average, black oystercatchers decreased incubation constancy by 39% in response to camping disturbance ($t = 26.95$, $P < 0.01$, $n = 37$, Figure 1). Nest attendance of males and females did not differ during control periods (Sign test M = -2.5, $P = 0.62$). Both males and females decreased nest attendance during disturbance periods (females: $\bar{x} = -0.20 \pm 0.08$, $P = 0.02$; males: $\bar{x} = -0.15 \pm 0.08$, $P = 0.07$; Figure 1) but there was no difference between sexes in level of response.

Replicate experiments were conducted on only 15 nests, most nests failed before we were able to complete all three experimental replicates. From this sample, we found no evidence that oystercatchers habituated to repeated experimental disturbance within seasons (Wilk's λ $F_{2,10} = 3.29$, $P = 0.08$; Figure 2). Oystercatcher pairs also did not habituate to disturbance between years; using data from the first experiments of 14 pairs studied in both years, we observed no trend in behavioral response (Wilk's λ $F_{1,13} = 0.14$, $P = 0.72$; Figure 3).

We found no evidence for an effect of behavioral response on the probability of nest survival. The best model of oystercatcher nest survival from 2001 – 2004 suggested that daily survival rate of nests varied annually, and declined as a quadratic function of date (Morse et al., *in review*). Adding the behavioral covariate to the best model structure did not improve model fit (Table 1). Additionally, a simple model with only the behavioral covariate fit the data less well than the model of constant daily nest survival. The parameter estimate for the behavioral covariate was –0.09 (95% CI: -0.50 –0.32). The estimated variance inflation factor ($\hat{c}$ = deviance of the global model/ df) was 4.05.

DISCUSSION

Black oystercatcher pairs spent substantially less time incubating nests during periods of experimental recreational disturbance. This disturbance caused both males and females to decrease incubation time. Despite female oystercatchers being larger and generally more aggressive (Andres and Falxa, 1995), we detected no difference between the sexes in level of response to experimental disturbance. Similar decreases in incubation constancy due to human activity have been observed for other avian populations (Yalden and Yalden, 1990; Steidl and Anthony, 2000; Verboven et al., 2001; Lord et al., 2001). Contrary to results of other studies, we did not observe any nest abandonment following repeated human disturbance (Piatt et al., 1990; Carney and Sydeman, 1999). Most pairs were incubating within five minutes of the end of an experiment, thus any direct effects of our experiments were short-term. Experimental disturbance was shorter in duration, but likely more intense and closer to the nest site, than most camping disturbance in Kenai Fjords National Park.

Although the overall effect was a substantial decline in incubation constancy, we observed a gradient of behavioral response to experimental disturbance. In the absence of disturbance, oystercatcher nests were incubated nearly constantly, with very little variation. During disturbance periods, however, some pairs continued to incubate constantly, while other pairs did not incubate at all. Frid and Dill (2002) suggested that from an evolutionary perspective, response to human disturbance is stronger when perceived risk is greater. They suggested plasticity in individual response is driven by an optimization of trade-offs, similar to those prey face when encountering predators. Perceived risk may have been influenced by concurrent risk of natural predation, similar to that demonstrated with American oystercatchers *Haematopus palliates* (Peters and Otis, 2005), but we lack the data necessary to test this hypothesis. Any number of additional factors could also influence an animal's perceived risk; further understanding of these individual decision-making processes is fundamental to understanding the mechanisms of disturbance (Gill and Sutherland, 2000).

There is abundant anecdotal evidence to suggest many avian populations habituate to repeated human disturbance, but few experimental data to support this assumption (Knight and Temple, 1995). Many studies have been unable to assess habituation effects, because that requires being able to track the response of known individuals through time. In this study we were able to examine the level of habituation at two temporal scales, within seasons and between years. We found no evidence that oystercatchers habituated to experimental disturbance at either temporal scale; behavioral response to disturbance did not change over time. This lack of habituation to human disturbance could suggest oystercatchers are more sensitive than other species to human disturbance. Alternatively, the intensity and duration of experimental disturbance may not have been sufficient to elicit, or detect, a habituation effect.

Intensity of behavioral response was not correlated with reproductive success. Conventional wisdom suggests that animals that are more responsive to human activity are more susceptible to adverse effects of human disturbance. More specifically, nests of birds that spend less time incubating due to human disturbance are presumably more vulnerable to predation or inclement weather. Nonetheless, we failed to detect such an effect; nests of pairs that were less attentive during experimental disturbance did not have lower daily survival rates. Our results provide some evidence in support of recent research suggesting that behavioral response may be a poor index to population-level impacts (Beale and Monaghan, 2004a; Gill et al., 2001). However, we may have failed to detect adverse effects because our experiments were short-term and our sample size was small. Alternatively, our results may be a localized effect, and highly dependent on local predator communities. In our study area, black bears *Ursus americanus* were one of the primary predators and may avoid areas with human activity, whereas the exact opposite effect has been shown for other predators, e.g., common ravens *Corvus corax*. The indirect effects of our experiments, and human disturbance in general, on local predator communities are largely unknown.

Linking behavioral response to population dynamics is the only means to identify cases where human disturbance is truly a problem for conservation of the species (Gill et al., 2001). Experimental disturbance clearly altered the incubation behavior of black oystercatchers. While this certainly had the potential to affect population dynamics through nest survival, we did not detect any effects of this behavioral change on nest survival rates. This study, combined with additional research on this breeding population (Morse et al., *in review*) provides evidence that black oystercatchers are resilient to low levels of recreational disturbance. Similarly, research on Eurasian oystercatchers *Haematopus ostralegus* has shown that human-caused disturbances are unlikely to affect populations (Lambeck et al., 1996; Gill and Sutherland, 2000). Yet in light of projected increases in recreational disturbance (Flather and Cordell, 1995), sound management plans are still needed for the conservation of black oystercatchers.

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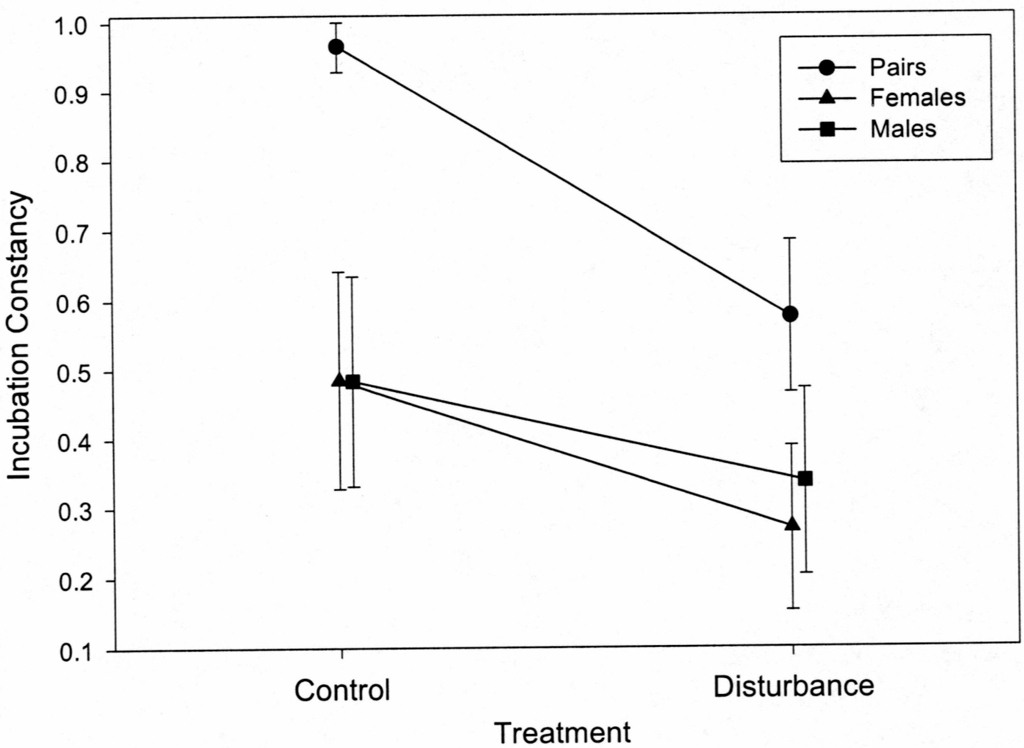

FIGURE 2-1. Incubation constancy (mean ± 95 CI) of black oystercatchers nesting in Kenai Fjords National Park during disturbance experiments conducted in 2004 and 2005. Data shown for first experiments only, for each sex (n = 30) and combined into pair level response (n = 37).

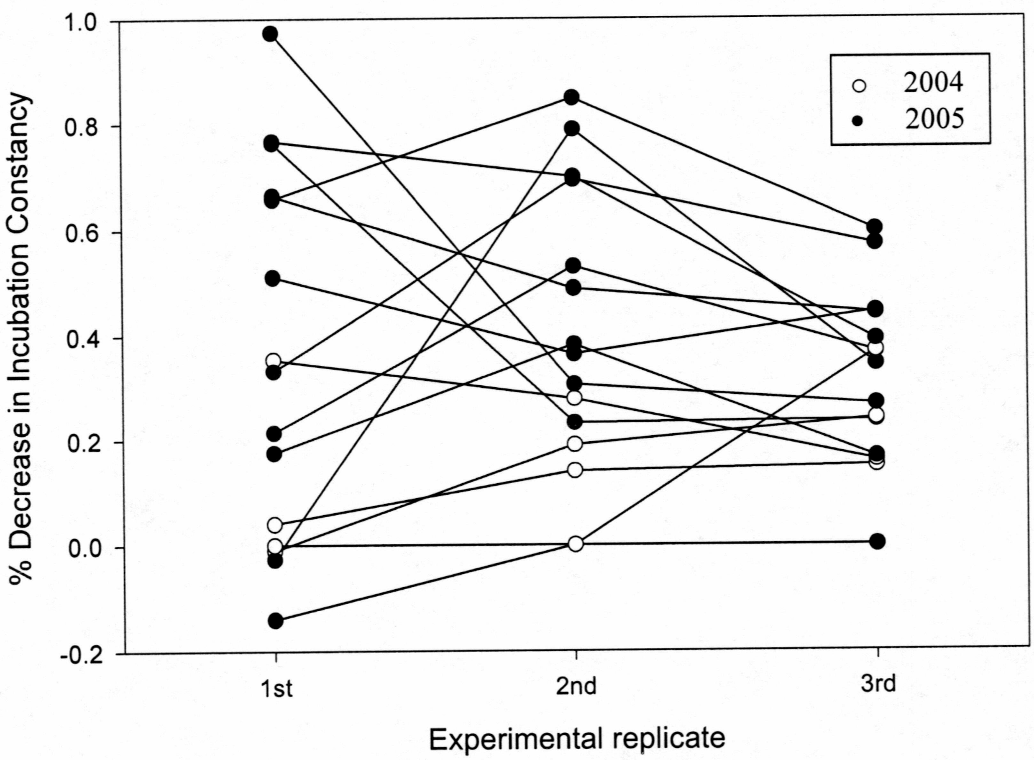

FIGURE 2-2. Within season variation in pair response of black oystercatchers to disturbance experiments conducted in 2004 and 2005 in Kenai Fjords National Park. Each line represents a black oystercatcher pair (with marked individuals), and each point marks the difference in incubation constancy between control and disturbance treatments.

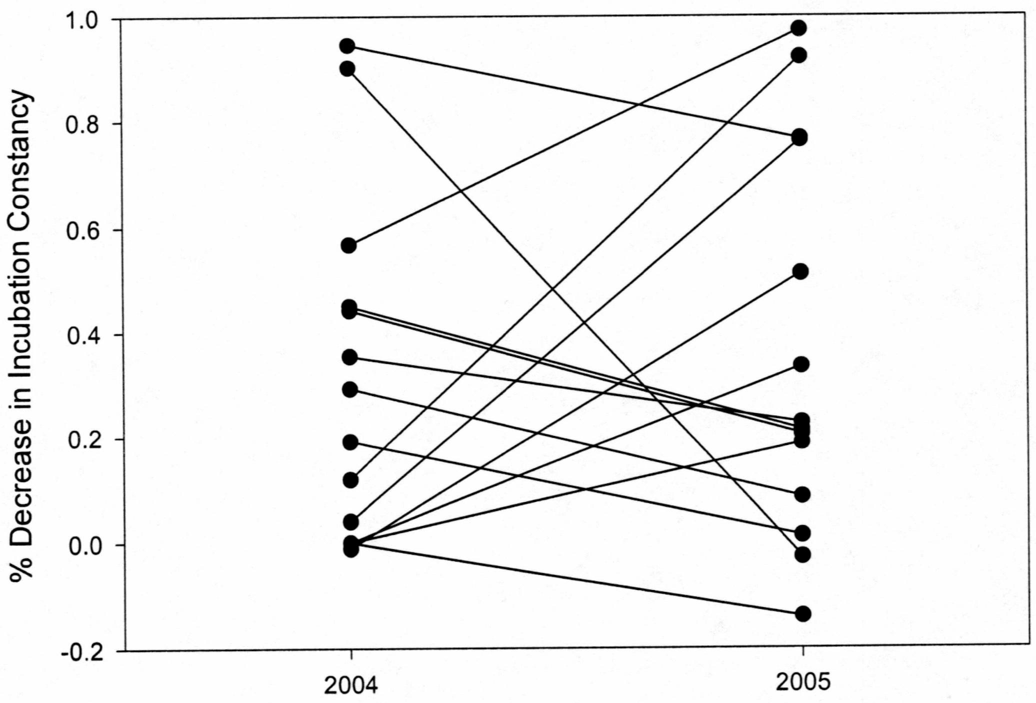

FIGURE 2-3. Inter-annual variation in pair response to disturbance experiments conducted on black oystercatchers at Kenai Fjords National Park in 2004 and 2005. Each line represents a black oystercatcher pair (with marked individuals), and each point marks the difference in incubation constancy between control and disturbance treatments of the first experiment conducted on that pair.

TABLE 2-1. Comparison of *a priori* models estimating behavioral impacts on daily survival rates of black oystercatcher nests at Kenai Fjords National Park, 2004-2005. Models were ranked based on Akaike's Information Criterion adjusted for small sample size (ΔAIC*c*).

NEST SURVIVAL [1]	K [2]	AIC_c [3]	*ΔAICc* [4]	w_i [5]	*DEV* [6]
Year + temporal² effects	4	141.85	0.00	0.70	133.77
Year + temporal² + behavior effects	5	143.71	1.86	0.28	133.59
Null model: DSR is constant	1	149.73	7.87	0.01	147.72
Behavior effects only	2	151.74	9.89	0.01	147.71

[1] Temporal² is a linear plus quadratic trend with season date
[2] No. of parameters
[3] Akiake's Information Criterion corrected for small sample size
[4] Difference in AICc from the best model
[5] Model weight
[6] Model deviance

GENERAL CONCLUSIONS

This study assessed the effects of recreational disturbance on black oystercatchers in a relatively pristine environment, where there were no roads or motorized vehicles on the beaches. Nonetheless, 25% of the entire breeding population in Kenai Fjords National Park was vulnerable to recreational disturbance because they nested on beaches that were popular campsites for kayakers. The level of recreational disturbance at these campsites was generally low and not consistent throughout the breeding season. The summer seasonal peak of human recreational use of beaches coincided with the brood-rearing stage at most sites. I found no evidence for different survival rates of nests or broods on these campsite beaches; thus the oystercatcher population breeding in Kenai Fjords appeared resilient to current levels of recreational disturbance.

Productivity of black oystercatchers was low (0.35 chicks fledged per pair), but similar to estimates reported from other studies (Andres and Falxa 1995, Murphy and Mabee 2000, Hazlitt 2001). Long-lived iteroparous species typically have low rates of annual reproductive success, but compensate by having many opportunities to breed in a lifetime (Stearns 1992). Annual estimates of productivity varied substantially, likely due primarily to fluctuations in local predator communities. Daily survival rate of nests was lower during periods of extreme high tides, providing further evidence that oystercatcher nests are particularly susceptible to flooding events (Andres and Falxa 1995). My results illustrate that the low productivity of black oystercatchers in Kenai Fjords National Park was primarily due to ecological, not direct anthropogenic factors.

Consistent with other studies (Groves 1982, Hazlitt and Butler 2001), I found black oystercatchers exhibited strong site fidelity to breeding territories; 95% of birds banded and resighted in the subsequent year returned to the same breeding territory. Most of the breeding territories identified during this study were used in multiple years. I could not directly assess the effect of recreational disturbance on site fidelity because very little recreational disturbance occurred during the critical period in early May when pairs were establishing territories. However, all of the breeding territories on campsite beaches were occupied in all five years of this study, with the exception of one territory in one year. These beaches should therefore be considered critical breeding habitats, and managed as such.

My field experiments clearly demonstrated that recreational disturbance caused oystercatchers to spend less time incubating nests. Individual pairs varied widely in their response to experimental disturbance, but on average pairs decreased incubation constancy by 39%. Despite this decrease, oystercatchers still incubated the majority (58%) of the experimental disturbance period. Contrary to a common assumption in the literature (reviewed in Nisbet 2000), I found no evidence that a decrease in incubation constancy was associated with a decrease in nest success. Strength of behavioral response was not correlated with probability of nest success, suggesting that behavior may be a poor index of susceptibility to disturbance (Beale and Monaghan 2004). Behavioral response to disturbance also did not change over time; oystercatchers did not habituate to experimental disturbance. Many species habituate to human activities (Hamitt and Cole 1987, Knight and Temple 1995), thus this could suggest oystercatchers are more sensitive than other species to human disturbance. Alternatively, the duration of experimental disturbance may not have been sufficient to elicit, or detect, a habituation effect.

This study demonstrated an effect of recreational disturbance on an individual level, but failed to detect any effects at the population level. Immediate effects of disturbance on individuals are generally easier to detect than long-term effects on populations (Knight and Cole 1995). Many factors may of course influence the population-level response to recreational disturbance, and effects may be indirect or delayed making them harder to detect. Only long-term experiments and monitoring can accurately assess the resiliency of populations to human disturbance. Future research on the effects of recreational disturbance on predator communities, and the effects of disturbance on the foraging ecology of oystercatchers, will best supplement this research and improve our understanding of, and ability to conserve, black oystercatcher populations.

MANAGEMENT RECOMMENDATIONS

With their low annual productivity, restricted movements during the breeding season, and dependence on intertidal habitats, black oystercatchers will remain vulnerable to human disturbance. Although I failed to detect any adverse effects of current levels of recreational disturbance on productivity of black oystercatchers at Kenai Fjords National Park, the observed increase in recreational activities over the course of this study, and the projected increase in the future is a cause for concern (Bowker 2001, Colt et al. 2002). The current levels of disturbance may be below a critical threshold level, beyond which birds fitness begins to be reduced and populations are impacted (Goss-Custard et al. 2006). Effective management plans are therefore needed which will constrain human disturbance below this threshold level of disturbance, or within the bounds of the species' resilience (Weaver et al. 1996). What these bounds are for black oystercatchers remains largely unknown, thus I encourage managers to take the 'precautionary principle' approach in managing recreational disturbance. Conservative management actions can be taken that incorporate aspects of the species life history traits to effectively minimize disturbance during critical breeding stages.

Managers of Kenai Fjords National Park have the unique opportunity to influence where people camp. Most recreationists establish their campsites near food storage lockers the park service has installed for bear protection. I recommend, where possible, these bear lockers be moved as far as possible from known oystercatcher nest sites to minimize potential disturbance. At some sites this is not possible due to terrain and limited availability of sites for tents. At present, the specific bear lockers I recommend moving are at South Verdant beach, and Abra and McMullen coves. Due to strong nest site fidelity it is unlikely these lockers would need to be moved frequently. However, new breeding territories could be established so this management strategy must be adaptive.

With the potential for a dramatic increase in recreational activities in the park, an important management strategy is to maintain accurate counts of human users, specifically at the breeding territories identified herein. Human-use thresholds can be established and if these thresholds were exceeded, then restrictive management actions could be instituted. Restrictions should be considered at both spatial (specific breeding territories) and temporal (critical breeding stages) scales. The most vulnerable breeding stages are during territory establishment (early – mid May), and hatch and early brood-rearing (site specific, early June – mid August). Currently there are no data available to decide what threshold levels of human disturbance should be; managers should therefore adopt conservative measures at first and adapt as future research and monitoring deems appropriate.

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